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Water Mist Machinery Space Fire Doctrine

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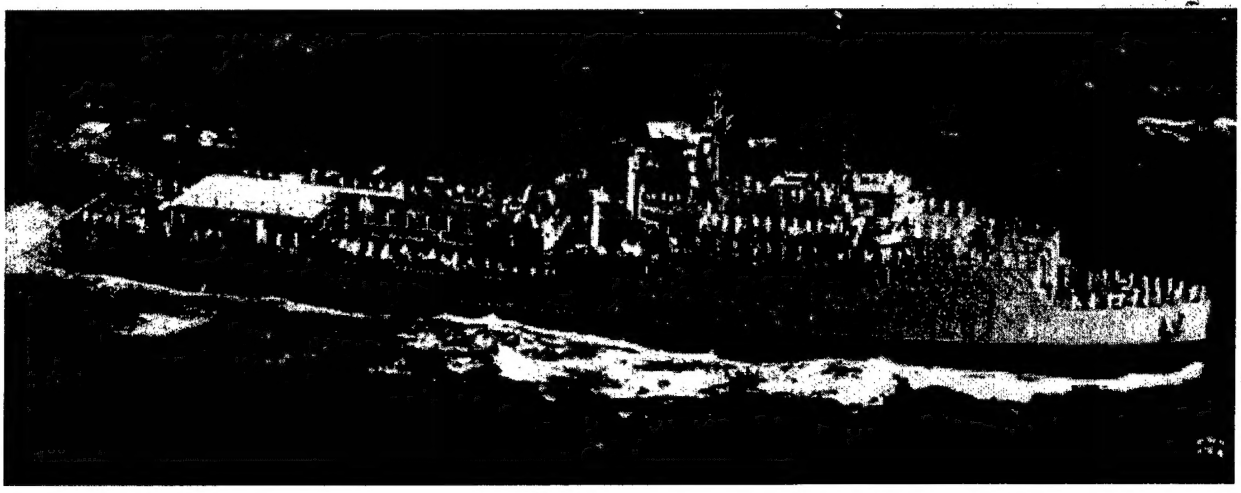

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14. ABSTRACT

While the Halon 1301 fire suppression systems installed in machinery spaces are very effective, environmental regulations have essentially prohibited the use of these systems for future ships. A high-pressure water mist system was developed as an environmentally friendly alternative for conventional Halon 1301 systems. Outlined in NSTM Chapter 555, Section 10 are procedures for dealing with an out-of-control class B fire in a machinery space protected with Halon 1301. Some of these procedures are unnecessary when water mist is used, since water mist can discharge for an extended period of time and offer continuous protection, the need to wait 15 minutes before entering the space is eliminated, and the affected space ventilation can be used during attack team entry. Also, due to the high thermal capacity of water, the potential exposure to hazardous post-fire conditions and the likelihood of fire spread are significantly reduced.

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CONTENTS

WATER MIST MACHINERY SPACE FIRE DOCTRINE

1.0 BACKGROUND

While the Halon 1301 fire suppression systems installed in machinery spaces are very effective, environmental regulations have essentially prohibited the use of these systems for future ships. A high-pressure water mist system was developed as an environmentally friendly alternative for conventional Halon 1301 systems. The procedures outlined in NSTM Chapter 555, Section 10 for dealing with an out-of–control class B fire in a machinery space protected with Halon 1301 includes:

1. Isolate the space, mechanically and electrically (if possible),
2. Don EEBDs/SEEDs and evacuate the space,
3. Activate the AFFF bilge sprinkling system,
4. Activate the Halon 1301 system,
5. If Halon is deemed unsuccessful, the backup Halon 1301 system is activated (if available),
6. Attack team enters space looking for residual fires and cooling hot surfaces, and
7. Ventilation is started once surfaces are cooled sufficiently

Some of these procedures are unnecessary when water mist is used, since water mist can discharge for an extended period of time and offer continuous protection, the need to wait 15 minutes before entering the space is eliminated, and the affected space ventilation can be used during attack team entry. Also, due to the high thermal capacity of water, the potential exposure to hazardous post-fire conditions and the likelihood of fire spread are significantly reduced.

2.0 MACHINERY SPACE FIREFIGHTING DOCTRINE FOR CLASS B FIRES IN SURFACE SHIPS WITH WATER MIST INSTALLED

The following water mist machinery space fire doctrine provides recommended changes to the Naval Ship Technical Manual (NSTM) Chapter 555- "Surface Ship Firefighting" germane paragraphs in Section 10. Detail comments follow:

555-10.1 PURPOSE *"no changes; The flowcharts (Figure 555-10.1) and any checklist associated with DCS, DCQ and /or DCAMS will need to be updated once the text of the Machinery Space Fire Doctrine is approved and finalized."*

555-10.2 INTRODUCTION *"no changes"*

555-10.3 DISCUSSION

Manuscript approved August 19, 2003.

555-10.3.2 FIREFIGHTING SYSTEMS CAPABILITIES AND LIMITATIONS. All ships are provided with one or more of the firefighting systems or equipment types described below. Each has responsibilities and limitations, which shall be known and understood by firefighting personnel to ensure quick and proper selection of equipment. It shall be noted that *water mist* is the primary firefighting agent for extinguishing class B fires in machinery spaces of surface ships except for those cases where the fire can be extinguished by hand held equipment.

555-10.3.2.4 Aqueous Film Forming Foam. *AFFF is a fluorinated surfactant, which produces firefighting foam that* can be applied either from hose reels inside or outside the space, a separate firefighting plug and hose with an inline AFFF eductor, or from bilge sprinkling. It is effective on bilge fires to vapor secure surfaces, prevent large-scale reflash, and for use during *attack team entry*. When a hose line attack is made to extinguish a flammable liquid fire, AFFF shall be used unless expended or out of commission. In this event, use of water fog is acceptable.

555-10.3.2.5 Aqueous Film Forming Foam Bilge Sprinkling. AFFF bilge sprinkling is a fixed fire extinguishing system designed to permit rapid extinguishment of bilge fires. The system *is installed* in conjunction with *water mist*. AFFF bilge sprinkling should be used to (a) prevent a fire by vapor securing a major oil leak in the bilges, (b) *independently extinguish bilge fires*, and (c) minimize the potential for reflash. When AFFF supply is limited to a 50-gallon tank, care must be exercised not to deplete the 50-gallon tank when using the bilge sprinkling system. AFFF bilge sprinkling should be operated when a major oil leak occurs.

555-10.3.2.6 Water Mist. *Water mist is a high-pressure fresh water total space fire protection system that discharges a fine mist from nozzles located in all levels except the bilge. The mist is effective at suppressing pool fires, oil spray fires and class A fires even if the fire is obstructed from direct contact with water spray from a nozzle. Water mist may not extinguish all fires particularly deep seeded class A fires, but the fires will not spread with water mist operating. The discharge rate is substantially less as compared with miscellaneous sprinkler systems and shipboard electrical equipment will not be damaged during and following water mist operation. Activation of the water mist system will automatically shut down ventilation in the affected main or auxiliary machinery spaces.*

555-10.3.2.7 HFP Fixed Flooding Systems. *Heptafluoropropane (HFP) is a compound of carbon, fluorine and hydrogen (CF_3-CHFC-CF_3) that is a non-ozone depleting substitute agent for protecting some self-contained engine enclosure modules. HFP is a colorless, odorless, and electrically non conductive gaseous agent that is approved for total flooding fire extinguishing applications in occupied spaces by the Environmental Protection Agency (EPA). Activation of the HFP system will activate visual and audible alarms and automatically shut down space ventilation, including dampers, where installed.*

555-10.3.3.2 Oil Spray Fires. *Oil spray fires may occur around fuel and lube oil strainers, recently repaired flanges and valves, and flexible line failures. An oil spray fire can grow out of control within seconds. Such fires are commonly fueled by an oil source that can not be quickly and completely secured. Fires that spread to the overhead insulation and cables, can produce sufficient products of combustion (flame, heat, smoke and gases) and spread to adjacent spaces. Securing the fuel source is the single most important step in controlling an oil spray fire. An oil spray fire resulting from the ignition of atomized flammable liquids, which can not be quickly and completely secured, should not be manually attacked with portable equipment. Past experiences and fire testing has demonstrated that a pressurized release of a flammable liquid can create a fire that is unapproachable. Life threatening conditions created by extreme heat, smoke, and toxic gases can occur, especially in the upper level, in as little as 60 seconds. Under such conditions the only prudent action, time permitting, is to secure the oil source, secure the propulsion plant, activate water mist, activate AFFF bilge sprinkling and leave the space or assemble in the Engineering Operating Station (EOS) to monitor the fire suppression operation. The AFFF bilge sprinkling system shall be activated again before attack team entry. Activation of the AFFF bilge sprinkling system before attack team entry will establish a fresh foam blanket and help to mitigate the potential for a bilge fire reflash.*

NOTE

The Engineering Operating Station's (EOS) ventilation is within the Collective Protection System (CPS) boundary and is separate from the machinery space Limited Protection System (LPS) ventilation system. Activation of the water mist system will not affect EOS ventilation system operation.

555-10.3.4.3 Secure the Source. The leak should be stopped as quickly as possible. *Leak isolation can be accomplished by securing the pump and closing system cutout or shutdown valves.* Even the application of a rag or bucket can significantly reduce the flow of oil and deflect it away from hot surfaces.

555-10.3.5 *INITIAL ACTIONS FOR* CLASS BRAVO FIRE SCENARIO.

555-10.3.5.3 Size Up *and Attack Localized Fire.* Assess the size and location of the fire. *The personnel responsible to size up the fire should be defined in ship procedures. For manned spaces, watchstanders should assess the severity of the fire. For unmanned spaces, roving patrol personnel or the EOOW (when video surveillance is available) may be used to size up the fire.* If the source can be secured quickly and the fire is localized, activate AFFF hose reel(s) and/or PKP extinguisher(s) and attack the fire. The range of PKP is 20 feet. In addition to toxic products of combustion in the space atmosphere, hydrogen sulfide gas may be present during the discharge of AFFF. See paragraph 555-2.7.10 for associated potential health hazards.

555-10.3.6 OUT-OF-CONTROL CLASS BRAVO FIRE SCENARIO. A class B fire, especially one that has burned for a period of time or is fed by an unsecurable oil source, can be out of control within seconds. *Water mist is designed to rapidly control and suppress class B fires. With a properly operating water mist system, the compartment atmosphere and surface temperatures will immediately be reduced. Water mist will also help to dilute any accumulation of fuel-rich gases, which will lessen the possibility of a flashback (the ignition of fire gases as they exit into fresh air and burn back into the fire compartment) during attack team entry.*

555-10.3.6.1 ***Fire Conditions.*** *Water mist should be operated when it is possible that the fire may become out of control. Possible out of control conditions include fire conditions that can not be assessed in less than a minute, a large fire, an oil source that can not be secured quickly, conditions hazardous to personnel in the space, and large amounts of smoke that may spread to adjacent spaces.*

NOTE

Water mist should be activated as soon as the fire is determined to be out of control. Water mist may be operated before space isolation and personnel egress is complete. It is recommended to restart the affected machinery space exhaust fan(s) if personnel are still in the space with water mist activated. The exhaust fan(s) should be secured once personnel egress is complete.

555-10.3.6.2 ***Personnel Egress.*** *Once the decision is made to activate water mist and AFFF bilge sprinkling, all personnel without adequate breathing protection (OBA or SCBA) should don their EEBD and exit the fire area using the nearest safe access. If at anytime, life-threatening conditions inhibit the ability of personnel in the space to locate and immediately don an EEBD, personnel should utilize the belt-worn Supplemental Emergency Egress Device (SEED) as described in* ***NSTM Chapter 077****. The EEBD should be donned when out of danger of immediate harm from heat and flames, if a breathable atmosphere can not be reached using the SEED. EEBDs and SEEDs shall not be used for firefighting purposes. Designated engineering personnel may assemble in the Engineering Operating Station (EOS), if available, to monitor and control the water mist fire suppression operations provided tenable conditions are maintained in the EOS and there are OBAs or SCBAs readily available for use.*

555-10.3.6.2.1 Non-CBR Threat Environment and **555-10.3.6.2.2** CBR Threat Exists. "*Recommend deleting these paragraphs. Most of this guidance is deemed not relevant for water mist protected ships and is already covered in paragraph* ***555-10.3.9.1.2****.*"

555-10.3.6.2.3 Muster Location. Ships should designate a location for *any personnel egressing a machinery space* due to fire. Different locations may be designated when a CBR threat exists verses a non-CBR threat. In any case, the location should be outside of the designated fire and smoke boundaries for the affected space.

555-10.3.6.2.5 Notification. The EOOW and *DC response organization* shall be notified that the following actions are taken:

a. Lighting to the space has remained on.
b. Water mist and AFFF bilge sprinkling systems activated and ventilation secured.
c. *Personnel egress is complete.*
d. DC response organization has been briefed on the location of the fire and plant status.
e. All remote actuators have been operated to verify system isolation. Verified that the DC Deck cutout valve to the AFFF hosereel stations in the affected space has been secured. All hatches, doors and scuttles to affected space are closed.

NOTE

Water mist fire suppression systems are ventilation tolerant (i.e., they do not loose suppression capability when the fire compartment can not be completely closed).

555-10.3.6.4 Monitoring Water Mist Operations. *Prior to attack team entry, conditions in the space should be monitored to confirm water mist is discharged in the space, ventilation has stopped, large fires are suppressed and space temperatures are tenable. See paragraph* ***555-10.3.10.***

NOTE

Water mist reduces visibility in the space. It may not be possible to confirm that all fires have been extinguished or to determine location of small fires that may not be detected without a close approach to the seat of the fire.

555-10.3.6.5 Improving Visibility During Water Mist Operations. *Prior to attack team entry, exhaust ventilation may be started with water mist operating to improve visibility in the space. See paragraph* ***555-10.3.10.***

555-10.3.6.6 Securing Water Mist. *The water mist system should be secured after the fire is believed to be out, smoke is contained, and the space temperatures are relatively cool.*

555-10.3.7 SMOKE CONTROL. Smoke control is comprised of the following areas.

555-10.3.7.1 Ventilation. The operation of ventilation systems is described where required in this doctrine. *Each ship shall supplement its doctrine with a list of fans that service the designated smoke control zones.* Weather deck supply intake and exhaust discharges should also be listed. The location of controllers, their designation and area served should also be listed.

555-10.3.7.2 Smoke Boundaries. Due to the large volume of dense smoke that typically is produced by class B fires, inner and outer smoke boundaries shall be set

quickly around accesses to the affected space. Smoke boundaries shall be set using structure that is at least fume-tight. Both the inner and outer smoke boundaries shall be set as described in paragraph **555-7.2.72.** ***The area between the inner and outer smoke boundaries is designated as the smoke control zone and is monitored by the DC response teams for smoke buildup and removal.*** *Only personnel with breathing apparatus should enter the smoke control zone once it is established. Each ship shall supplement its firefighting doctrine with a list of designated smoke boundaries for the machinery spaces.*

555-10.3.7.2.1 *CPS should be operated to maintain positive pressure on the damage control deck. This will reduce the spread of smoke and provide cooling air-flow at the back of the attack team during space entry. If CPS is ineffective at keeping smoke from the DC deck, the smoke ejection system (SES) should be operated if available.*

555-10.3.7.2.2 Active Desmoking. "*Recommend deleting this paragraph for ships equipped with SES.*"

555-10.3.8.3 Fire Boundaries. *Fire boundaries are established around the affected space to confine the fire. These boundaries are generally the water tight bulkheads and decks immediately adjacent to the affected space. If operating properly, water mist maintains cool boundary temperatures. Therefore, investigators may be used in place of designated boundarymen for monitoring machinery space fire boundaries.*

555-10.3.9.2 Clothing. *Anti-flash hoods, firefighting gloves, fire resistant engineering coveralls, and OBA/SCBA are the minimum requirements for attack team personnel when water mist is operating. For instances where water mist is not adequately controlling the fire, firefighter's ensembles are needed for the attack team.* Support personnel such as phone talkers, plugman, electricians and medical personnel, outside the fire boundary, shall wear battle dress uniforms as described in **NSTM Chapter 077, Section 5, Utility Clothing**. Firefighting personnel exposed to a CBR threat should wear the firefighter's ensemble or appropriate CBR protective gear as described in **NSTM Chapter 470**.

555-10.3.9.3 Hoses. *As a minimum the attack team shall use a single attack 1-1/2 inch AFFF hose, with vari-nozzle. A second backup hose should be manned to render assistance as needed. The second hose should be supplied from an in-line eductor, high capacity or low capacity foam station. The Scene Leader decides the resources needed, including the need for an attack team leader, a second hose to enter the machinery space, and a NFTI.*

555-10.3.10 ATTACK TEAM ENTRY. *To maintain an escalating attack on the fire, attack team entry should be attempted as soon personnel are ready and safe conditions can be confirmed. Attack team personnel can be formed from a rapid response team, a repair party organization or a combination of both. The attack team should consist of a primary and backup hose, however the entry of the primary hose should not be delayed if awaiting the staging of the second hose and associated personnel. The functions of the attack team are to investigate and determine the status of the fire space conditions, locate*

and extinguish any remaining fires, ensure the source of the oil is secured, and cool any remaining hot surfaces. To be most effective, the investigation should start on the lower level of the machinery space and then move up to the upper levels. The general guidelines for consideration upon attack team entry are as follows:

a. *When water mist and AFFF bilge sprinkling have been activated:*

1. *Operate AFFF bilge sprinkling a second time for at least two minutes before entry to prevent the possibility of an unsecured fuel source degrading the initial foam blanket.*
2. *Attack team entry should be attempted as soon as possible after the water mist is activated.*
3. *Effective operation of the water mist system should be monitored prior to attack team entry by:*
   (a) Feeling bulkheads for temperatures near the desire access.
   (b) Monitoring exhaust vent discharge for smoke.
   (c) Monitoring conditions through the EOS windows or peephole in the escape trunk doors. The NFTI can not be used for this purpose because the NFTI can not see through glass.
4. *If there is evidence that water mist did not activate, the attack team should consider indirect cooling high within the machinery space to help thermally manage the conditions in the space. The indirect cooling action will create adequate turbulence in the region around the fire, water vapor/ steam and vitiated gases will dilute the oxygen, and the fire size will be reduced. This indirect cooling action will also help to improve personnel safety through reduced exposures to hazardous conditions and reduce the likelihood of backdraft and/or flashback conditions.*
5. *Attack team entry should be made through the main access entrance or the escape trunk. In most instances it is desirable to use the escape trunk because the trunk provides a protected path to the lower level where the space temperatures will be cooler and entry will be made at the same level or below any residual fire. Prior to entry the space exhaust ventilation can be restored to improve visibility.*
6. *After entry to the space, the water mist system should be secured as soon as possible. Full-scale testing has determined that most class B fires will be extinguished in less than 60 seconds. Previous testing also revealed that water mist performance is enhanced as fire size increases (i.e., large fires are more easily suppressed than very small fires). Initial space investigation may be expedited by having the lead DC personnel carry portable extinguishers as they navigate throughout the machinery space.*
7. *Once the fire is reported out, set reflash watch and complete fire overhaul.*

555.10.3.11 DESMOKING ATOMOSPHERIC TESTING, DEWATERING and REMANNING.

555-10.3.11.1 Desmoking. *Combustible gases may be present if the water mist system malfunctioned and the exhaust ventilation was not used during attack team entry. Under*

these conditions desmoking with installed ventilation can proceed with minimal risk when the fire has been manual extinguished and overhauled, AFFF bilge sprinkling has been operated, the source of oil secured, the space cooled, all fuel washed into the bilges, and no damage sustained to the electrical distribution system. Circuit breakers and other protective devices that tripped automatically shall be left in the tripped position until system damage has been assessed. If fans are fully operational, run all fans on high speed for a minimum of 15 minutes to remove smoke and toxic gases. If the installed system is partially or fully inoperable, desmoking will take longer, but can be accomplished by using positive pressure provided by the ship's total protection or adjacent limited protection machinery space ventilation systems.

555.10.3.11.1.1 "*Recommend deleting this paragraph. Germane guidance has already been included in paragraph* **555.10.3.11.1**."

555.10.11.2 Atmospheric Testing. *Desmoking shall precede atmospheric testing because oxygen analyzers will not operate reliably if the sensor is exposed to excessive moisture or comes in contact with particulate found in post-fire atmospheres.* When the space is clear of smoke, test for oxygen, combustible and toxic gases. The level of oxygen, as referenced in **NSTM Chapter 074, Volume 3, Gas Free Engineering**, shall be between 19.5 to 22 percent, combustible gases shall be less than 10 percent of the lower explosion limit, and toxic gases should be below their threshold limit values before the space is certified safe fore personnel without breathing apparatus. Shipboard personnel authorized to conduct post-fire atmospheric tests for the purpose of certifying the space safe for personnel are Gas Free Engineers and Gas Free Engineering Petty Officers. *The post-fire atmosphere resulting from fires suppressed with water mist will be less toxic in comparison to fire suppressed with gaseous agents because most acid gases are soluble in water and water sprays also have the ability to dilute hydrocarbon gas concentrations. Therefore Carbon Monoxide (CO) can be used as an index gas for validating the absence of toxic gases in post-fire atmospheres for fires suppressed with water mist. The basic assumption is that if CO has been reduced to safe levels by ventilation, any other toxic gases present will be similarly reduced. A CO meter reading of 25 parts per million (ppm) or lower is required before personnel are allowed to work inside a space without OBA/ SCBAs.* If AFFF has been discharged, a test for hydrogen sulfide, shall also be conducted. All post-fire atmospheric tests should be conducted near the center and all four corners on all levels. At least one satisfactory test must be obtained at each location tested. Instruments used shall be approved by the National Institute of Occupational Safety and Health Administration, or NSTM. In a CBR environment tests in accordance with **NSTM Chapter 470** also shall be performed. See **NSTM Chapter 470** for decontamination methods if the space has been exposed to CBR contamination. For additional information see paragraph 555-7.10.3.

APPENDIX A

Amended Guidance for Gas Turbine or Diesel Engine Enclosure Firefighting for Ships with Heptafluoropropane (HFP) Installed

555-8.5 GAS TURBINE OR DIESEL ENGINE ENCLOSURE FIREFIGHTING

555-8.5.1 Gas turbine and diesel engines are commonly shrouded in enclosures for cooling purposes and noise reduction. Historically, fires occur with these engines when lube oil or fuel oil gage lines, flexible lines, or filters fail and release flammable or combustible liquids onto hot surfaces. *For this reason, gas turbine generator or diesel engine enclosure modules on halon-free ships are fitted with a self-contained heptafluoropropane (HFP) total flooding fire extinguishing system. HPP is a halon replacement compound of carbon, fluorine, and hydrogen (CF_3-CHF-CF_3). It is colorless, odorless, and electrically non-conductive. It suppresses fire by a combination of chemical and physical mechanisms without affecting the availability of oxygen. HFP is clean, leaves no residue, thereby eliminating costly after-fire cleanup. HFP is stored in steel containers, at 360 PSIG at 70 °F (25 bars at 21 °C), as a liquid, with nitrogen added to improve the discharge characteristics. When discharged, HFP liquid vaporizes at the discharge nozzle and is uniformly distributed as it enters the fire area. HFP is approved for total flooding fire extinguishing applications in occupied spaces by the Environmental Protection Agency (EPA) and appears on the Significant New Alternatives Policy (SNAP) list of acceptable substances for ozone depleting substances.*

NOTE

If an accidental discharge of HFP system occurs, ventilation should be restored to the enclosure module for at least fifteen (15) minutes before entry. Although HFP is not life threatening, the design concentration used of may exceed the cardiotoxic Lowest Observable Effect Level (LOAEL) of 10.5 percent. The rational for allowing higher design concentrations above the LOAEL to improve HFP fire suppression performance and reduce acid gas production includes:

1) *The acceptable cardiac sensitization toxicity protocol has a longer exposure time (5 minutes) than expected to be required for egress.*
2) *The Occupational Safety and Health Administration (OSHA) does permit human exposure to increased chemical concentrations (in general) if adequate provision is made for protective equipment (i.e., EEBD,SEED).*

These systems may be designed with flame and/or heat sensors to automatically detect fire and sound an alarm, securing engines and module ventilation, and discharge *HFP*. Manual operation of the *HFP system* also can be accomplished inside the machinery space or remotely at the console in the Engineering Operating Station (EOS) or Damage Control Central (DCC). Reflash may occur following initial extinguishment by *HFP*, due

to air movement and leakage that dilute the gas concentration. In the event of a class B enclosure fire beyond the capability of portable extinguishers, the following procedures apply;

1) Upon indication of fire, shut down the engine, report the fire, and activate the *HFP* system.

WARNING

HFP, when exposed to fire or other hot surfaces at temperature above 1300 °F, will produce Hydrogen Fluoride (HF) gas. Over exposure to HF gas, in concentrations greater than three (3) parts per million (ppm), will have the following effects on humans:

- *Corrosive and irritating to the eyes.*
- *Corrosive and irritating to skin and all living tissue.*
- *When injected, corrosive and irritating to the gastrointestinal system.*
- *When inhaled, corrosive and irritating to upper and lower respiratory tract; causes chemical pneumonitis and pulmonary edema which could be fatal.*

2) Breakout and man an AFFF fire hose. EOOW determines if backup is required including additional resources.

3) Visually monitor the enclosure, including the exhaust stack, for signs of continuing heat and smoke production, for fifteen (15) minutes prior to *entering* the module.

4) If the system does not discharge or a reflash occurs during the 15 minute waiting period, activate the second shot, if available, or prepare for attack team entry.

5) Upon issuance of entry authorization, start enclosure ventilation, crack open an access door and attack fire from the doorway with an AFFF hoseline.

6) If a reflash does not occur during the 15 minute hold time, ventilate the enclosure module for 15 minutes prior to entry.

CAUTION

When exhausting smoke and HF gas from the enclosure module, take caution not to expose personnel to smoke and gases. Do not enter the enclosure module if the HF gas level is above 3ppm. Refer to the MSDS for HF gas.

7) Once fire is reported out, wash down complete interior and all equipment, within the protected space, with fresh water.

8) In the event of a class C electrical generator fire, extinguishing agent may be applied with hand held equipment as soon as the generator is isolated from the switchboard and the prime mover is secured. It is permissible to fight a class C generator fire as soon as the generator is isolated and before it stops running.